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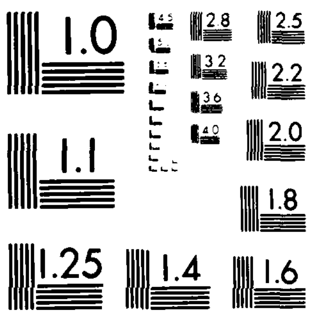

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TECHNIQUES FOR REDUCTION AND ANALYSIS OF UPPER ATMOSPHERE RESEARCH DATA

Paul F. Hilton
Stephen C. Phillips

Systems and Applied Sciences Corporation (SASC)
6811 Kenilworth Avenue
Riverdale, Maryland 20737

February 15, 1983

Final Report for Period January 16, 1980 - January 15, 1983

Approved for public release; distribution unlimited

AIR FORCE GEOPHYSICS LABORATORY
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
HANSCOM AFB, MASSACHUSETTS 01731

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Twelve data processing assignments for which SASC developed and implemented reduction and analysis techniques are described. Data were derived from sensors on board geophysical research rockets and balloons. Samples of listings and plots are included.

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PREFACE

This Final Report is prepared and submitted by Systems and Applied Sciences Corporation (SASC) under Contract No. F19628-80-C-0058 with the Air Force Geophysics Laboratory (AFGL). It covers the period January 16, 1980, to January 15, 1983.

Work was performed for the Analysis and Simulation Section (SUNY) of the AFGL Computer Center Branch, Office of Research Services, AFGL, Hanscom AFB, MA 01731.

The contract was a three-year Firm Fixed Price Level of Effort contract, with a value of $434,798. However, reduced funding in FY82 ($69,999) and FY83 ($20,000) reduced the contract value to $322,132.

SASC technical personnel assigned to the contract, varying with funding level, were:

Paul F. Hilton, M.S., Principal Investigator
Charles F. Ivaldi, Jr., B.S., Programmer
Barry A. Mareiro, Jr., Junior Programmer
Stephen C. Phillips, Junior Programmer
Scott D. Hamilton, Junior Programmer.

At the inception of the contract, assistance was rendered by Donald C. Norquist, M.S., Joan M. Ward, A.B., Gail M. Bertolini, A.B., and Jeff Childs. Program management was provided by Alan M. Gerlach, Ph.D.

* * * * * *

The Principal Investigator thanks Robert E. McInerney, Robert Raistrick, and John F. Kellaher, SUNY, for their cooperation and technical guidance; and Sanford B. Smith and Dorothy H. Quinn, SUNO, for their invaluable assistance in the development of an interactive graphics package. The dedication and excellent programming support provided by SASC employees Charles F. Ivaldi, Jr., Barry A. Mareiro, Jr., Stephen C. Phillips, and Scott D. Hamilton are gratefully acknowledged. Typing of this and other reports by Dianne M. Connor is appreciated.

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I. INTRODUCTION

The Analysis and Simulation Section (SUNY) of the AFGL Computer Center Branch, Office of Research Services, provides a broad spectrum of technical support to AFGL scientists in such areas as statistical and numerical analysis, computer simulation, and reduction and analysis of atmospheric and near-earth space environmental data. The major efforts are in those areas of geophysical research that utilize data transmitted from sensors flown on research balloons, rockets, and satellites. Systems and Applied Sciences Corporation provided technical services in the reduction and analysis of rocket- and balloon-borne sensor data.

Reduction of scientific data requires a wide variety of analytical methodologies, such as numerical techniques, including averaging, smoothing, and filtering of data; and polynomial and Fourier approximations to model the data. Software development was the responsibility of SASC technical personnel; occasionally, existing routines were obtained from the AFGL Computer Center library. Analyses were generally run on the AFGL CDC 6600 computer system.

Of primary importance in successful processing of experiment data is a thorough understanding of the purpose of the experiment, form of the data, intermediate stages in the processing stream, anticipated results, and formats for data presentation. Discussions between SUNY and SASC of these processing details often eliminated delays and permitted flexible system designs.

In the three-year contract period SASC processed experiment data from twelve AFGL scientists. No two data sets were handled in exactly the same way. However, a general step by step methodology was developed by SASC that lent itself to flexibility and scheduling of milestones. It also allowed for retracing steps when calibrations were changed or data sets were superseded.

At the start of each problem SASC was provided with: (1) an analog strip chart, (2) Digital Work Request, and (3) Rocket Data Analysis Information. Along with these standard pre-processing inputs, SUNY furnished SASC with the appropriate R-tape(s). This tape contained experiment data that had been telemetered in real time to a ground recording station. These data were packed in twelve-bit computer words. In order to proceed with data handling on the CDC 6600, it was necessary to unpack the R-tape into 60-bit words. This was accomplished by software developed by SUNY and tailored by SASC. The R-tape was then returned to CC (Computer Center) archives.

Once the data were unpacked, quality checks were performed on the unpacked tape. SASC developed software to flag timing errors or improper sampling rates. Usually, timing errors were corrected by adding a constant. However, occasionally it was necessary to develop an algorithm to smooth the times, or even to obtain a new R-tape.

The unpacked data tape, free of timing problems, was the primary data base. The information on this tape was usually in counts that were converted into telemetry volts and subsequently into engineering units. Since the R-tape was returned to the archives, the irreducible data tape served as the primary source of experiment data and remained the point of origin if problems were encountered downstream in the data reduction process.

If the equation that converts counts to telemetry volts was known, a new data base was generated immediately. However, if the calibration was not known, it was necessary to list data in the vicinity of the in-flight calibrations. The on-board telemetry system is able to send a step-pulsed signal (0 - 2.5 - 5.0 volts). The normal lower band edge is represented by a count value of -1638, corresponding to zero telemetry volts, and the normal upper band edge has a count of 1638, which translates into five volts. The analyst averaged the values at the upper and lower band edges and also at the middle of the band, 2.5 volts (zero counts). Usually there was a slight shift in the calibration scale, on the order of 70 counts. A linear equation was derived from the sample listing and used to create a data base in telemetry volts. A sample listing of counts and corresponding telemetry volts was made and an analysis done to check the validity of the derived calibration equation. In most cases a fine-tuning of the calibration equation yielded the appropriate telemetry voltages. When the SUNY Contract Manager was confident that the appropriate linear equation to convert counts into telemetry volts had been obtained, the data were ready to be changed into engineering units.

The calibration equations used to give physical meaning to the count data received at the ground station are the result of work by the instrument technicians in their laboratory. The simplest equation is linear and valid for any value of the telemetry voltage. The more complicated equations involve logarithmic scales and may be valid only over a specified range.

Computer application of the calibration equation(s) to the raw data produced a data base on magnetic tape with information in units having physical meaning. This data base was ready to be reduced, listed, or displayed. If the sampling rate was 1,000 samples per second (SPS), it was generally

sufficient to list the data at 20 - 50 SPS. This avoided unnecessary and extensive listings that would take up computer time and space. If the experiment dictated a high sampling rate at specified times, it became a matter of retrieving the data from the original engineering unit tape.

Data may be displayed by pen-and-ink plots, microfiche, or Tektronix. Pen-and-ink plots are best suited for later reproduction in technical publications. Microfiche plots permit the most plots in the least amount of space. Copies of microfiche plots are suitable for publication purposes but yield to pen-and-ink because of slight distortions in the reproducing process. Plots which are copied directly from the Tektronix are useful in the preliminary stages of plotting the data, because the turn-around time is short.

Finally, after the data were reduced, trajectory and attitude data were merged with the experiment data. Standard trajectory and attitude tapes were provided to SASC to create a final tape containing all the information. If listings or plots of the combined data were required, they were supplied.

II. TECHNICAL PROBLEM SUMMARIES

In this section, each of the twelve problems for which SASC developed and implemented software for reduction and analysis of digitized data is summarized.

A. Rocket Performance Tests

Initiator: Edward F. McKenna (Aerospace Instrumentation Division)

Duration: January 1980 - July 1980

Assignment:

The objective of this effort was to provide performance data in listed and plotted formats, in support of post-burnout thrust studies of an AFGL research rocket launched on August 7, 1979.

Summary:

Both frequency modulation (FM) and pulse code modulation (PCM) data were supplied to SASC. Data from four accelerometers and two pressure gauges on the motor instrument module were listed from 19:45:55 (t-5 sec) to 19:53:00 (t+180 sec) in FM telemetry volts. Calibrations were applied to these data and listings of the data in engineering units were produced. The data in engineering units were then plotted on microfiche at 0.5 seconds per graph.

Word 2 (digital payload separation rate) on PCM telemetry tape from the payload instrument module was listed in counts. Word 22 (analog separation rate) was listed in counts and subsequently in telemetry volts. Words 2 and 22 were plotted on microfiche from t-5 sec to t+180 sec in 0.5 second intervals.

IRIG's 15, 16, and 14 (x-, y-, and z-axis accelerometers) were listed in PCM counts. After applying appropriate calibrations, these data were listed in telemetry volts and then in engineering units. Microfiche plots of the data in engineering units were made at 0.5 sec intervals for the time t-5 sec to t+180 sec.

Data processing in this effort was representative of most of the problems assigned. Figs. 1 and 2 are typical flow charts used to structure the data reduction. The basic procedure consisted of unpacking an R-tape, converting telemetry data to engineering units, and listing and displaying the data.

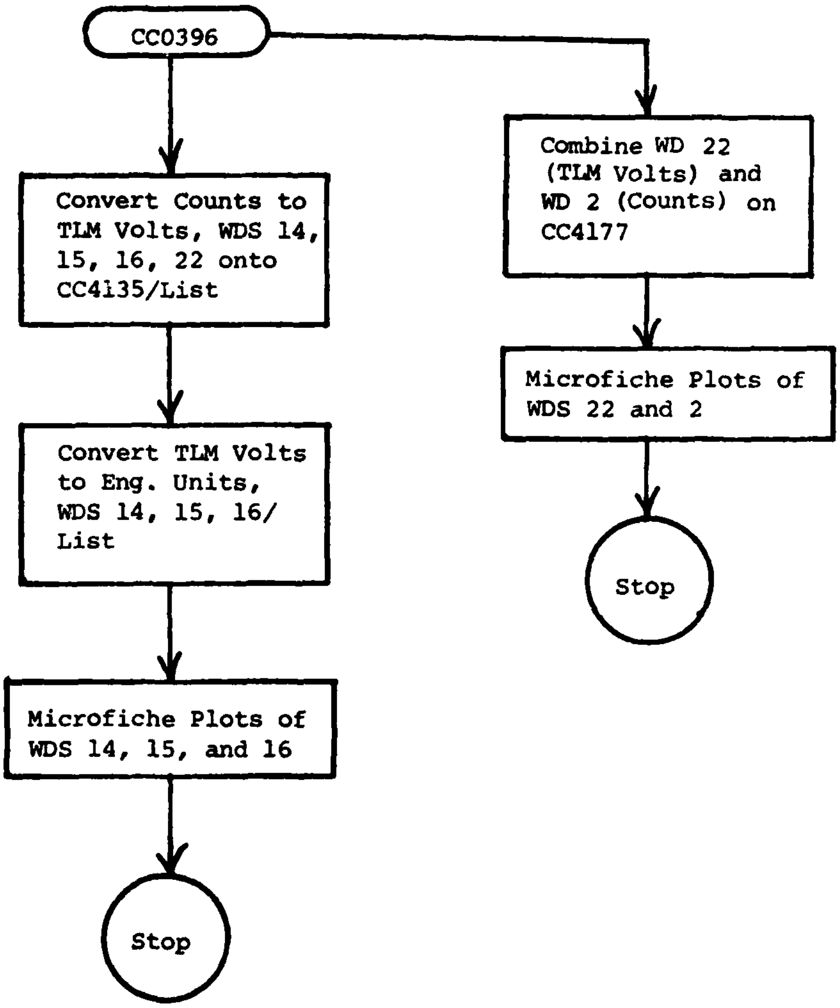

Fig. 1. Flow Chart for PCM Data

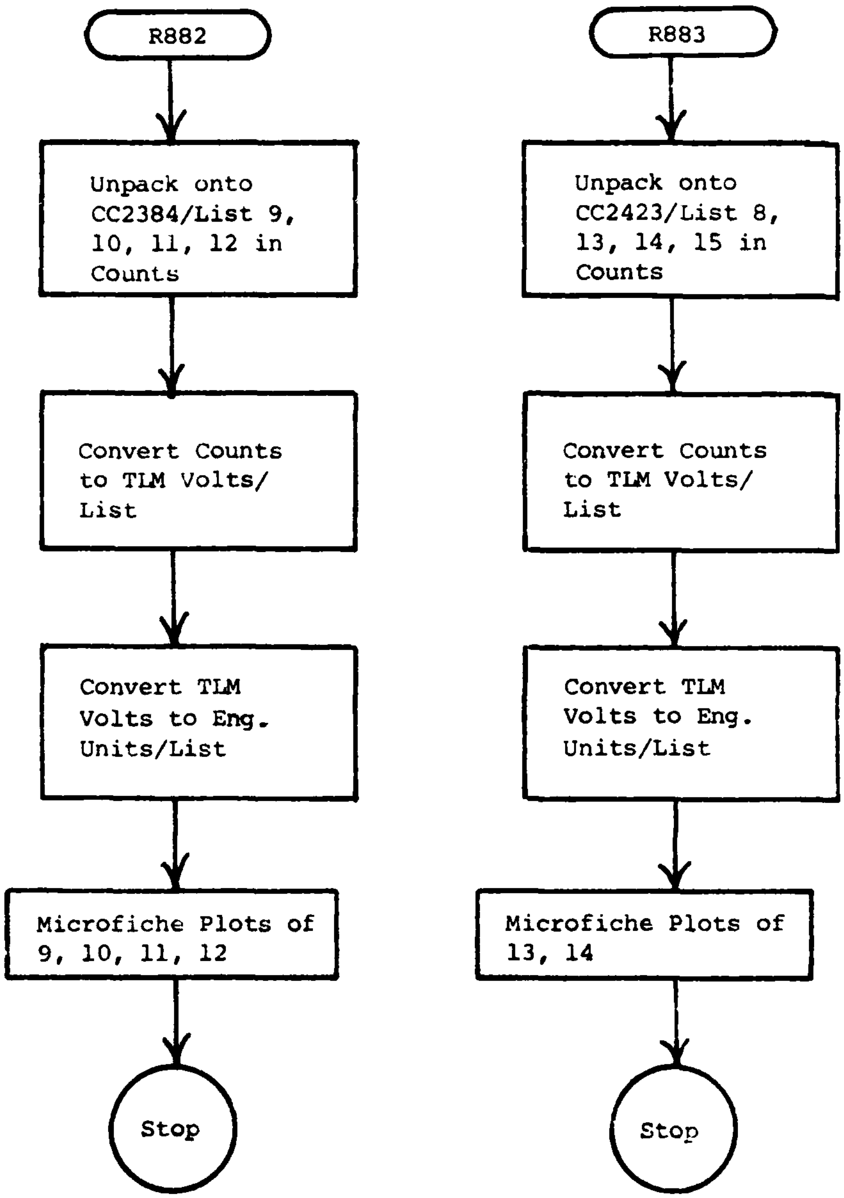

Fig. 2. Flow Chart for FM Data

History of the problem is shown in Table 1. At completion, a list of tapes created by SASC (Table 2) and software developed by SASC (Table 3) were provided to SUNY. No formal software documentation was required; however, detailed program listings and documentation were retained by SASC.

TABLE 1. HISTORY OF PROBLEM NO. 3111

3/18/80	SASC received two FM tapes, R883 and R882
4/4/80	Unpacked R883 onto CC2423 and R882 onto CC2384
4/7/80	Listed both FM tapes by counts
4/11/80	Converted FM data from counts to telemetry volts
4/17/80	Received PCM data tape CC0396
4/28/80	Listed PCM data Words 14, 15, 16, and 22 in counts
5/6/80	Listed PCM data Words 14, 15, 16, and 22 in telemetry volts
5/7/80	Wrote Word 22 (telemetry volts) and Word 2 (counts) onto CC4177
5/8/80	Listed both FM data tapes in engineering units; listed Words 14, 15, and 16 (PCM) in engineering units
5/22/80	Provided SUNY with a sample plot of PCM data
6/2/80	Produced microfiche plots of PCM data
6/4/80	Recalibrated IRIG 13 (FM data)
6/9/80	Produced microfiche plots of FM data

TABLE 2. TAPES CREATED BY SASC FOR ROCKET PERFORMANCE TESTS

TAPE	LABEL	WRITE STATEMENT
CC2384	MCKENNATAPEA	IWD,NG,(D((I+J-1)*IWD),J=1,IWD),J=1,NG) [TIME,9,10,11,12,9,10,11,12,9,10,11,12]
CC2423	MCKENNATAPEB	Same as CC2384 [TIME,8,13,14,15,8,13,14,15,8,13,14,15]
CC4135	PCMMCKTMVDATA	TIME,Word 14,Word 15,Word 16,Word 22** (TMV Data)
CC4166	PCMMCKEUDATA	TIME,Word 14,Word 15,Word 16,Word 22 (Engineering Data)
CC4177	PCMMCKWDS2A22	TIME,Word 22,Word 2 (22 in TMV; 2 in counts)

** Word 22 is in TMV on both tape CC4135 and CC4166

TABLE 3. SOFTWARE DEVELOPED BY SASC FOR PROCESSING (LIST/DISPLAY) PCM AND FM DATA

A. PCM Data

1. Conversion of counts to telemetry volts
2. Conversion of telemetry volts to engineering units
3. Microfiche plots of Words 2 and 22
4. Microfiche plots of IRIG's 14, 15, and 16

B. FM Data

1. Conversion of telemetry volts to engineering units
2. Microfiche of Words 9, 10, 11, and 12
3. Microfiche of Words 13 and 14

B. Auroral-E Reformat Tapes

Initiator: Michael Smiddy (Space Physics Division)

Duration: March 1981 - June 1981

Assignment:

Data from the Auroral-E experiment were stored on magnetic tape in a packed 12-bit word format. The objective was to repack these data tapes into 24-bit words to make them suitable for processing on a Burroughs computer.

Summary:

The basic software foundation for this problem was a SUNY-developed program designated DQ, a generalized unpacking routine that converts 12-bit words into 60-bit CDC words. It was used as a subroutine in a bit packing program developed by SASC. The procedure followed was to unpack the R-tapes from 12-bit words, reformat the words into 60-bit CDC structure, and repack into 24-bit words.

Difficulties were experienced in the initial stages of the unpacking because of timing errors in the recording device. When the trouble areas were identified, SASC was able to work around the problem. Finally, two reformatted tapes in 24-bit words were produced. Tape A001, which contains data from t+60 to t+108 sec, corresponds to R943; tape A002, which contains records for the times t+180 to t+230 sec, related to R944.

No software documentation was required.

C. Rocket Spectrometers

Initiator: Donald E. Bedo (Aeronomy Division)

Duration: January 1980 - January 1983

Assignment:

The purpose of the research program was to obtain absolute values of solar flux in vacuum UV and near UV regions, by means of spectrometers flown on five rockets. Instructions to SASC were:

1. Segment the raw data into trouble-free sections, unpack, and list;

2. Plot segments on microfiche: for single-channel spectrometers (Flts. A and B), raw count (log scale) vs. wavelength (linear scale); for two-channel spectrometers (Flts. C, D, and E), raw count vs. step number;

3. Identify bad values caused by instrument noise; remove and replace with interpolated values;

4. Re-list and re-plot raw data on microfiche;

5. Apply instrument-related calibration factors to the raw data to correct for nonlinearity of wavelength scales, detector nonlinearity, scattered light, filter attenuation, and variation in spectral resolution across the wavelength range;

6. Convert values in raw count to photon flux for each wavelength;

7. List all data with respect to time, telemetry value of wavelength, corrected value of wavelength raw count, corrected raw count, and flux in units of photons/$cm^2 \cdot$ sec;

8. Calculate, list, and plot average fluxes; and

9. For publication purposes, display data on the red ink Calcomp plotter, list, and place on card files.

Summary:

Processing of all five rocket flights followed a general pattern: software developed for Flts. A and B was used for Flts. C, D, and E with minor changes.

The first step in data analysis and reduction was to unpack the 12-bit R-tape into 60-bit CDC words. After the R-tape was unpacked onto a CC (Computer Center) tape, it was returned to the AFGL tape archive. The CC tape contained data in digitized form. Each frame of data consisted of universal time of day in seconds, a sync word, wavelength, and photon count.

Since the data were in digitized form, the next step was to create a tape that would allow the analyst maximum flexibility in processing and would minimize computer time. A complete listing of the raw data was produced.

Data transmission from the rocket had been subject to errors in the mechanical arrangement of the spectrometer and in the radio signal to the ground station. The first problem was easily corrected by allocating the appropriate steps per wavelength for each spectrometer. The second problem required development of an algorithm to identify bit transmission difficulties and make an appropriate correction. About 80 to 90 percent of the errors were eliminated by the algorithm. The remaining errors were identified by the project team, and a large number of data cards was keypunched to make the necessary changes.

Finally, a corrected data base was stored on magnetic tape. At the same time a paper listing (Table 4), which included the original count values, and microfiche plots (Fig. 3) were made. The final data base was used to create several pen-and-ink plots that were incorporated in a technical publication.

To eliminate noise in the data base several filters were developed. These filters were applied to Flts. B, C2, and D2. The results were displayed on microfiche.

Several computer programs were documented and submitted to SUNY.[1] For a more detailed description, including the error removal algorithm, see Hilton (1981).[2]

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1. Analysis and Simulation Branch Project/Problem Library Documentation Worksheets, Problem No. 4002: AREDUC/BEDOAVE, November 19, 1981; BEDOFLTAPLOT, March 17, 1982; BEDOAVERAGE, March 17, 1982.

2. Hilton, P. F., 1981: Reduction and Analysis of Rocket-Borne and Balloon-Borne Sensor Data. AFGL-TR-81-0036, Scientific Report No. 1, Contract No. F19628-80-C-0058, Systems and Applied Sciences Corporation. AD A104037

TABLE 4. REFINED DATA LISTING OF FLIGHT B

BEDO FLIGHT B APRIL 21,1977

TIME (HHMMSS)	WAVELENGTH (ANGSTROM)	COUNT	
17/ 3/ 9.136	1853	24	
17/ 3/ 9.141	1853	27	
17/ 3/ 9.145	1853	24	
17/ 3/ 9.150	1853	25	
17/ 3/ 9.154	1853	30	
17/ 3/ 9.158	1853	24	
17/ 3/ 9.163	1853	33	
17/ 3/ 9.167	1853	31	
17/ 3/ 9.172	1853	26	
17/ 3/ 9.176	1853	28	
17/ 3/ 9.181	1853	31	(21)
17/ 3/ 9.185	1853	33	
17/ 3/ 9.190	1853	40	
17/ 3/ 9.194	1854	38	
17/ 3/ 9.199	1854	26	
17/ 3/ 9.203	1854	38	
17/ 3/ 9.208	1854	24	
17/ 3/ 9.212	1854	27	
17/ 3/ 9.217	1854	33	
17/ 3/ 9.221	1854	35	
17/ 3/ 9.225	1854	34	
17/ 3/ 9.230	1854	34	
17/ 3/ 9.234	1854	34	
17/ 3/ 9.239	1854	35	
17/ 3/ 9.243	1854	38	
17/ 3/ 9.248	1854	42	
17/ 3/ 9.252	1855	35	
17/ 3/ 9.257	1855	29	
17/ 3/ 9.261	1855	27	
17/ 3/ 9.266	1855	23	
17/ 3/ 9.270	1855	18	
17/ 3/ 9.275	1855	26	
17/ 3/ 9.279	1855	26	
17/ 3/ 9.284	1855	31	
17/ 3/ 9.288	1855	34	
17/ 3/ 9.292	1855	30	
17/ 3/ 9.297	1855	27	
17/ 3/ 9.301	1855	33	
17/ 3/ 9.306	1855	38	
17/ 3/ 9.310	1856	38	
17/ 3/ 9.315	1856	37	(13)
17/ 3/ 9.319	1856	34	
17/ 3/ 9.324	1856	26	
17/ 3/ 9.328	1856	34	

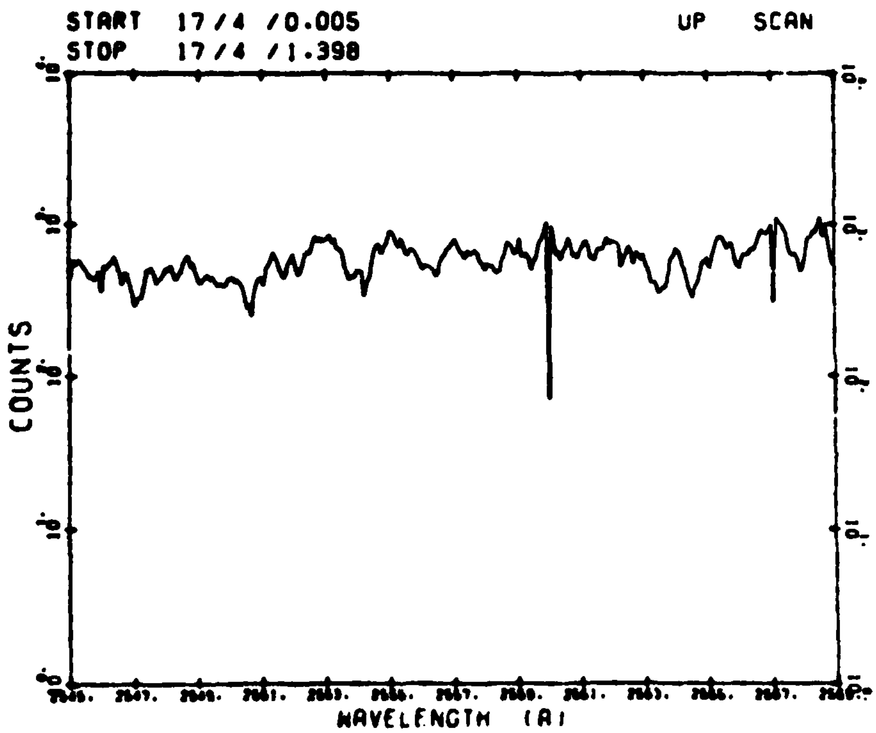

Fig. 3. Sample Microfiche Plot of Flight B

D. Gerdien Condensers

Initiator: Rocco S. Narcisi (Aeronomy Division)

Duration: January 1980 - September 1981

Assignment:

Objective of the research program was to measure positively charged particles and negatively charged particles in the earth's upper atmosphere by means of Gerdien condensers flown on two research rockets. Each rocket carried two condensers — one for positive particles, one for negative particles. For each Gerdien there was a data channel and a sweep voltage channel. Instructions to SASC were:

1. Determine the start and stop times for each sweep;

2. Plot on microfiche (counts vs. time) several seconds of time series selected through inspection of strip charts;

3. Convert counts to voltage using linear conversions, and plot;

4. Determine switching times by the intersection of extrapolated lines from consecutive sweeps;

5. Convert the telemetry voltage output of each data channel to current, using supplied calibration data and making semilog interpolations between calibration points;

6. List all data for the first twenty sweeps, including sweep voltage, data telemetry, and data currents;

7. Consult with the Contract Manager regarding further processing; the final step being the merging of sensor data with angle of attack (angle between Gerdien and velocity vector) data.

Summary:

The standard on-board telemetry system sends a step-pulsed signal (0 - 2.5 - 5.0 volts). The normal lower band edge is represented by a count value of -1638, which corresponds to zero telemetry volts, and the normal upper band edge has a count of 1638, which translates into five volts. However, both flights had slight deviations from the normal count scale. To correct this problem SASC calculated the average count at each end of the scale, and in the middle. A straight line equation was derived to convert PCM counts to telemetry volts, and applied to each data base.

SASC was supplied with a set of calibration points for each Gerdien to convert telemetry voltage to ion current. Since neither a first nor se-

cond order equation fit the calibration points satisfactorily, a straight line curve was used for each consecutive pair of points.

The initial listing of data indicated that the start of each sweep was buried in signal noise and thus not identifiable. Consequently, SASC developed a technique that analytically determined the start of sweep. This method involved the approximating of two adjacent sweeps with a straight line fit. The intersection of these two lines yielded the start of sweep.

Once the start of sweep was determined, data tapes with corresponding listings of sweep voltage and ion current were generated. Microfiche plots of all the data were also produced (Fig. 4). One of the key requirements of the research project was to determine the slope of the current at selected locations. Since the laboratory Project Scientist was the best person to choose the points, SASC developed an interactive graphics package for him. The software was designed for the user who does not possess any programming ability.

Fig. 5 is a typical product of the interactive graphics routine. The +'s are points selected by the user. On the right hand border the pairs of points to be saved are listed. These are also stored on a permanent file.

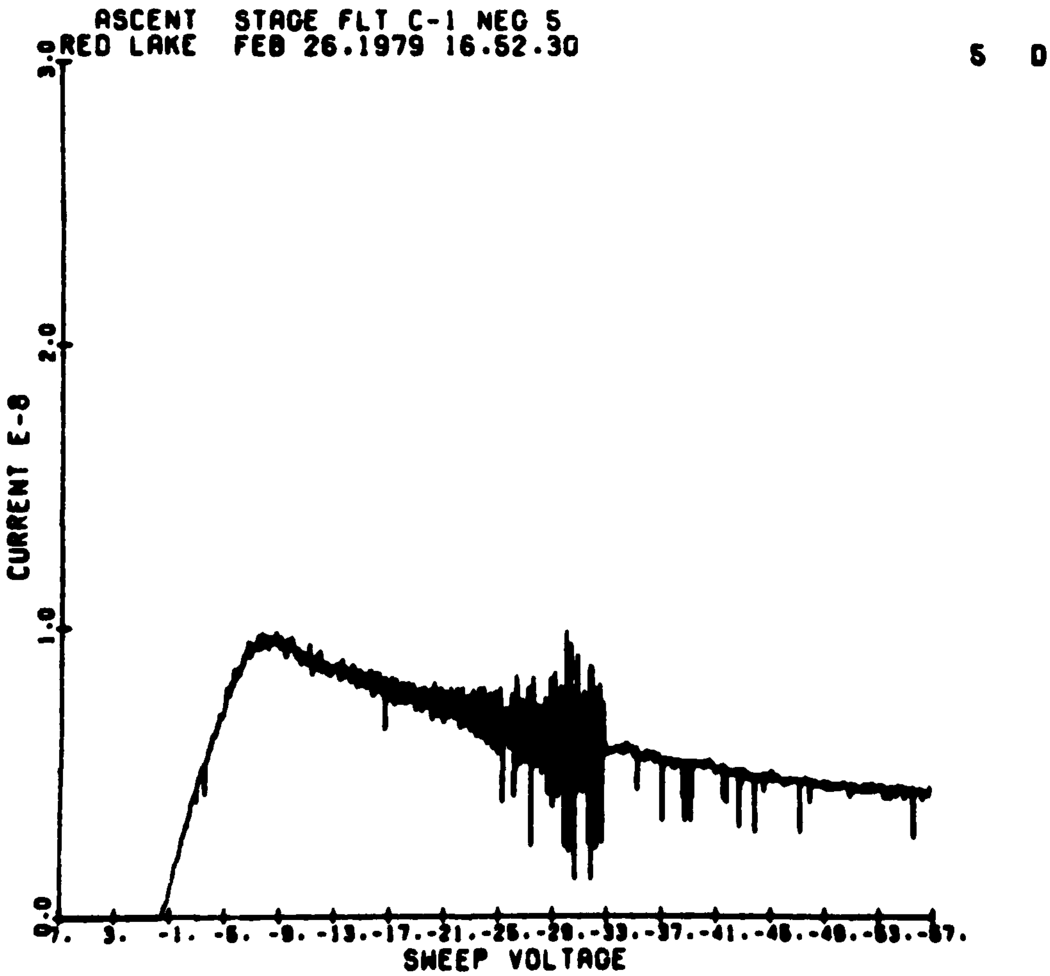

Fig. 4. Typical Plot of Sweep Voltage vs. Current for Scan 5, Downstroke

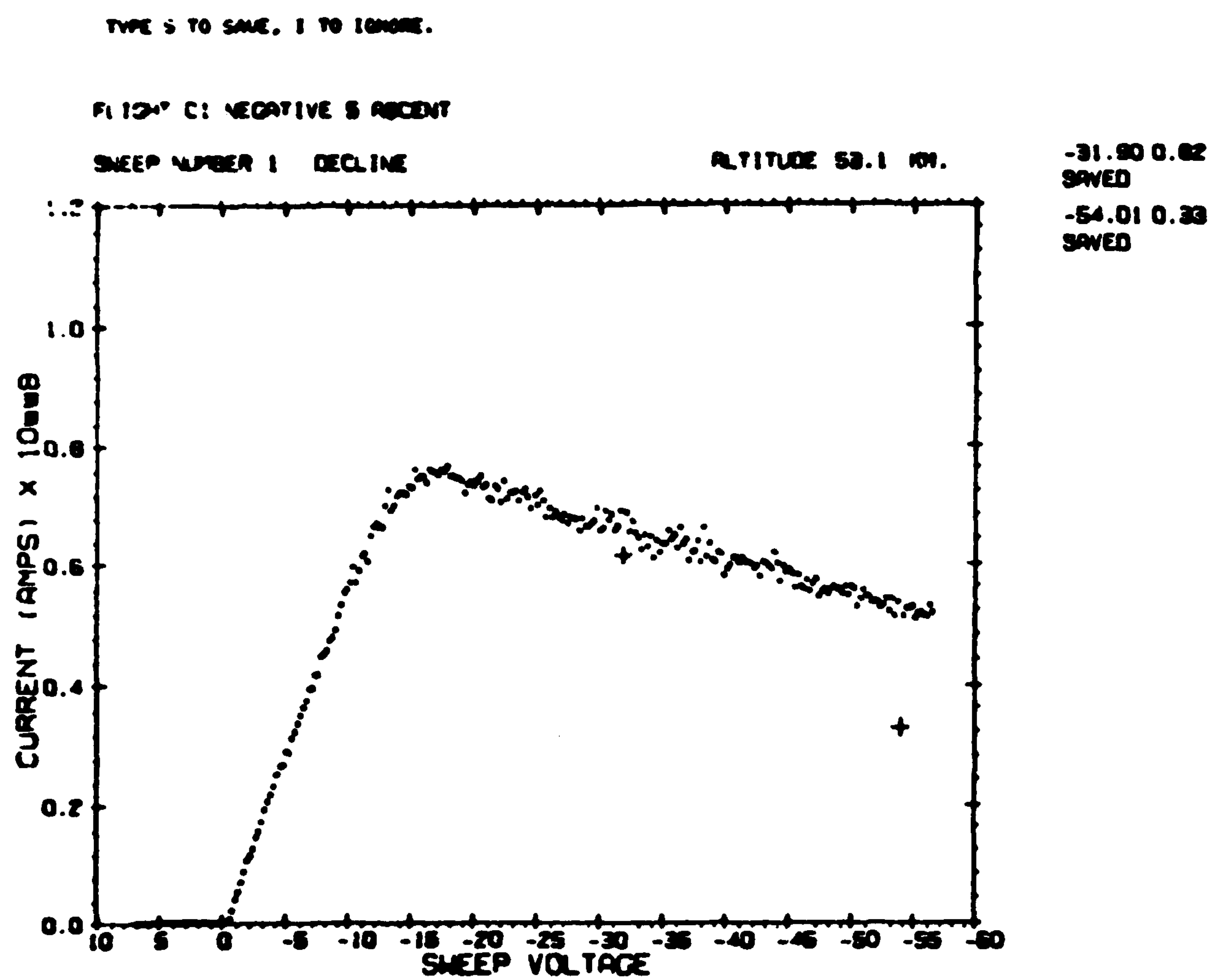

Fig. 5. Display of Sweep Voltage vs. Current, Demonstrating the Interactive Graphics

E. Balloon-Borne Spectrometers

Initiator: L. Alton Hall (Aeronomy Division)

Duration: June 1980 - January 1983

Assignment:

The experiment consisted of a balloon-borne spectrometer continuously scanning back and forth in wavelength (two scan lengths were available), recording solar intensities on two separate detectors. The wavelength scan was a stepping motion, 100 steps per second, and a data frame was generated for each step. Detector #1 covered 3214 - 2026 Å in long scan; detector #2 covered 3113 - 1909 Å.

The first step in the data reduction plan specified to SASC was to list and plot one complete scan in order to assess data quality and desired formats. Significant amounts of the data (distributed in time) were then to be produced, to ascertain the extent of variation with time, altitude, and other factors for the whole flight. Software for computing solar intensities and absorber concentrations was then to be devised and used to extract those quantities for an 8-hour balloon flight.

Summary:

Three balloon flights (H78-15, H80-18, and H81-9) produced over twenty hours of data. Because of the vast amount of data it was necessary to process only the particular scans that were of interest to the laboratory scientist.

Processing each scan followed a set pattern. The first step was to unpack the appropriate R-tape in the vicinity of the scans to be analyzed. The scans before and after the interval of interest were unpacked to economize computer time and anticipate future needs.

Once the scans were unpacked, binary words were combined to make a raw data set. A conversion equation was applied to the wavelength counter for each detector to obtain the corresponding wavelength in angstroms. Finally, the digitized counts from each detector were converted to solar flux.

The final data arrangement was listed on paper in such a format that any timing problems in the data transmission were flagged. Where there were timing errors SASC inserted changes recommended by the laboratory scientist.

Many scans were presented on magnetic tape. Several scans were produced in both listed paper form and pen-and-ink plot.

Appropriate documentation was prepared.[3]

3. Analysis and Simulation Branch Project/Problem Library Documentation Worksheets, Problem No. 3130: HLLLST, HLLPLT, HLCCA, July 15, 1981.

F. EXCEDE: SPECTRAL

Initiator: Robert O'Neil (Optical Physics Division)

Duration: January 1980 - September 1981

Assignment:

The EXCEDE: SPECTRAL experimental apparatus consisted of a rocket-borne electron accelerator and a large array of ultraviolet, visible, and infrared sensors. The optical instruments (six primary sensors and ten secondary sensors) measured the atomic and molecular emissions induced in the atmosphere by the pulsed accelerator.

The analysis was projected for SASC as follows:

1. Determine vehicle trajectory — (altitude, velocity) vs. time (separate requests);
2. Determine aspect:
   (a) vehicle — pitch, yaw, roll, azimuth, and elevation;
   (b) probes — azimuth, elevation, and accelerator pitch angle;
3. Reduce each optical sensor (16 instruments) to radiant intensity vs. time;
4. Reduce the electron accelerator operating parameters to units of voltage (kilovolts) and current (amperes) vs. time; and list and plot the voltage and current for each of the four gun modules;
5. Calculate ratios of selected emissions to gun module power and examine ratios as a function of altitude;
6. Plot selected spectral band profiles as a function of altitude;
7. Plot intensities of selected emissions as a function of ambient molecular density.

Summary:

The data output for each instrument was initially processed separately. The ultraviolet and visible spectrometer tapes, previously generated by another contractor, presented many problems. After the source of the difficulties was finally identified as uncorrected time values, extensive listings of the tape contents were required before the tapes could be corrected.

Calibration equations were applied to raw data to obtain engineering units. Listings of data from all of the instruments were produced, along with many microfiche plots (Fig. 6).

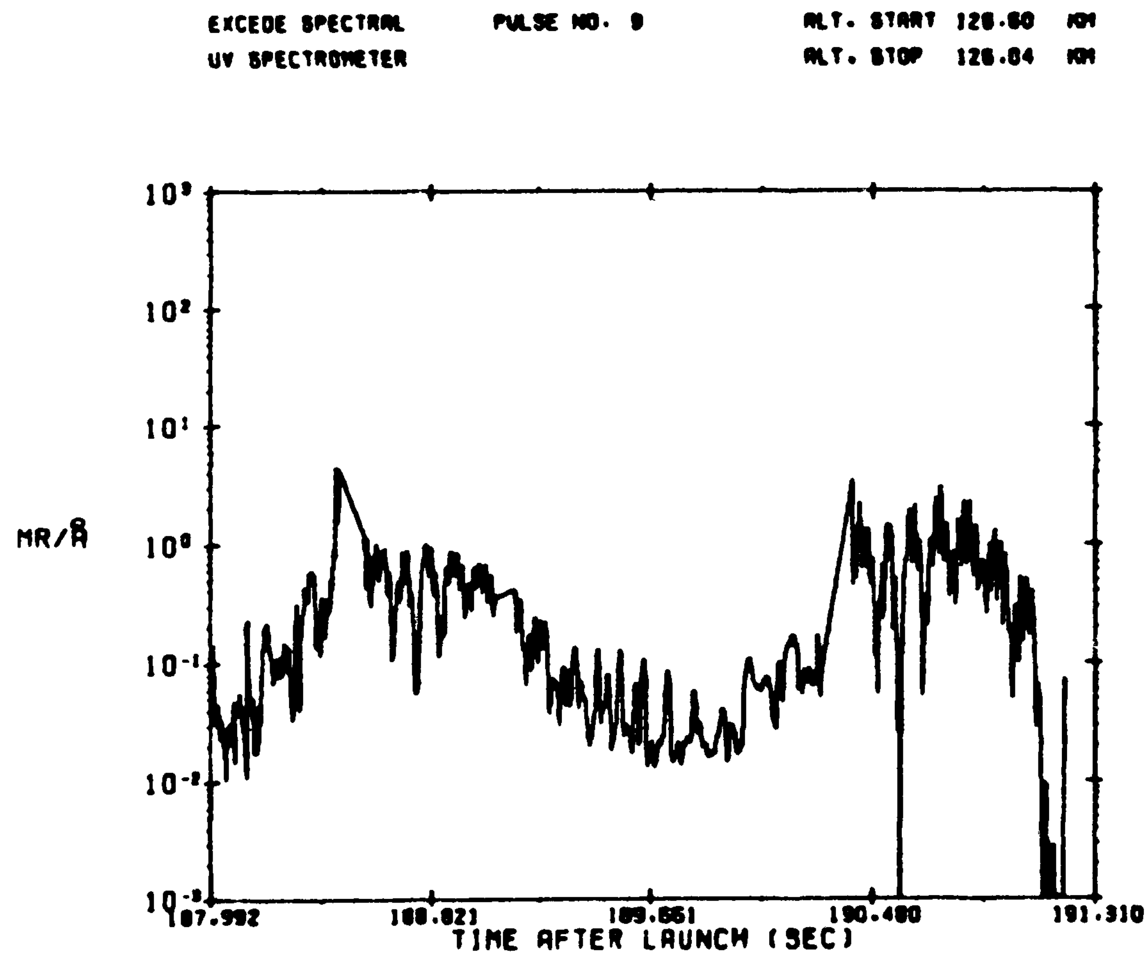

Fig. 6. Plot of Photon Density as a Function of Time after Launch

When all of the raw data for each of the instruments were converted to engineering units they were merged. However, when microfiche plots of several instruments were made, time discrepancies with the original strip charts appeared. It was then necessary to change the time values on some of the instrument tapes. For example, all four electron guns (Fig. 7) were aligned after a previous plot showed spurious lag.

Several versions of calibration routines were used with the photometers. Data lists and plots brought out errors in the instrumentation. A final data set was generated; these data were plotted along with the electron accelerator guns on microfiche.

Since no software was judged to be of future value, no documentation was produced. A complete list of the data tapes was provided to SUNY.

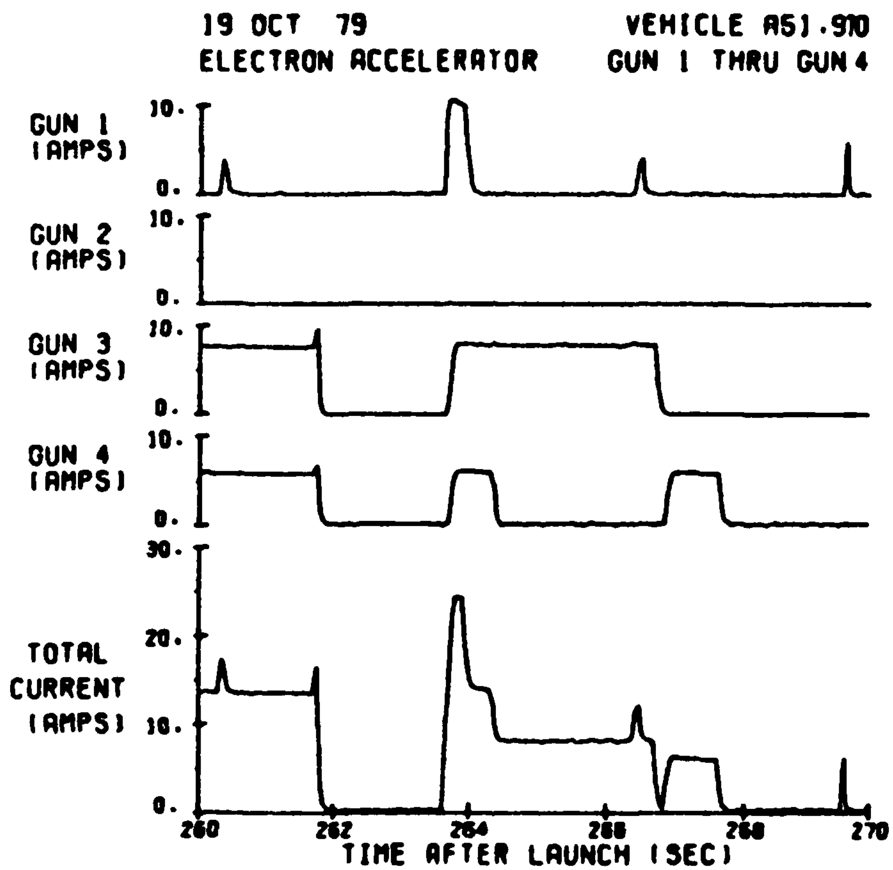

Fig. 7. Simultaneous Display of Output from All Four Electron Guns, along with the Sum

G. Auroral UV/Optical Spectroscopy

Initiator: Duane E. Paulsen (Aeronomy Division)
Duration: March 1981 - January 1983

Assignment:

Two spectrometers and a UV photometer were flown on AFGL rocket A13.031 on March 7, 1981. One spectrometer covered short wavelengths from 130 to 257 nanometers and the other, long wavelengths from 290 to 562 nanometers. Each spectrometer obtained a complete spectrum at 2.0 nanometer resolution every 2.0 seconds.

SASC's assignment was to analyze the spectral profile of various bands to estimate temperature. The photometer (507 nanometers with a full width at half maximum of six nanometers) collected emission data from the NO_2 recombination continuum. The nitric oxide density profile was to be computed using volume emission rate, atomic oxygen density, and a temperature-dependent rate constant.

Additionally, displays of instrument output by step and altitude were to be made on both CRT and pen plotter. Three-dimensional plotting software was to be developed to display radiance as a function of longitude and latitude.

An overall view of the data requirements for this project is shown on the flow chart (Fig. 8).

Summary:

Standard procedures were employed to obtain the raw data base for each of the three instruments. A quadratic equation was used to approximate the altitude. The altitude information was merged with the measurements, which were then converted to engineering units in standard SUATEK format. Data were displayed as a function of both time and altitude according to specified step intervals.

Values of sum, mean, and standard deviation were calculated and displayed as functions of time/altitude. For each step interval a polynomial curve was obtained to approximate radiance as a function of altitude (Fig. 9).

There were many requests for displays of data over specified intervals. Smoothing methods were utilized on occasions. At times, enlargements over certain altitudes or radiance values were needed.

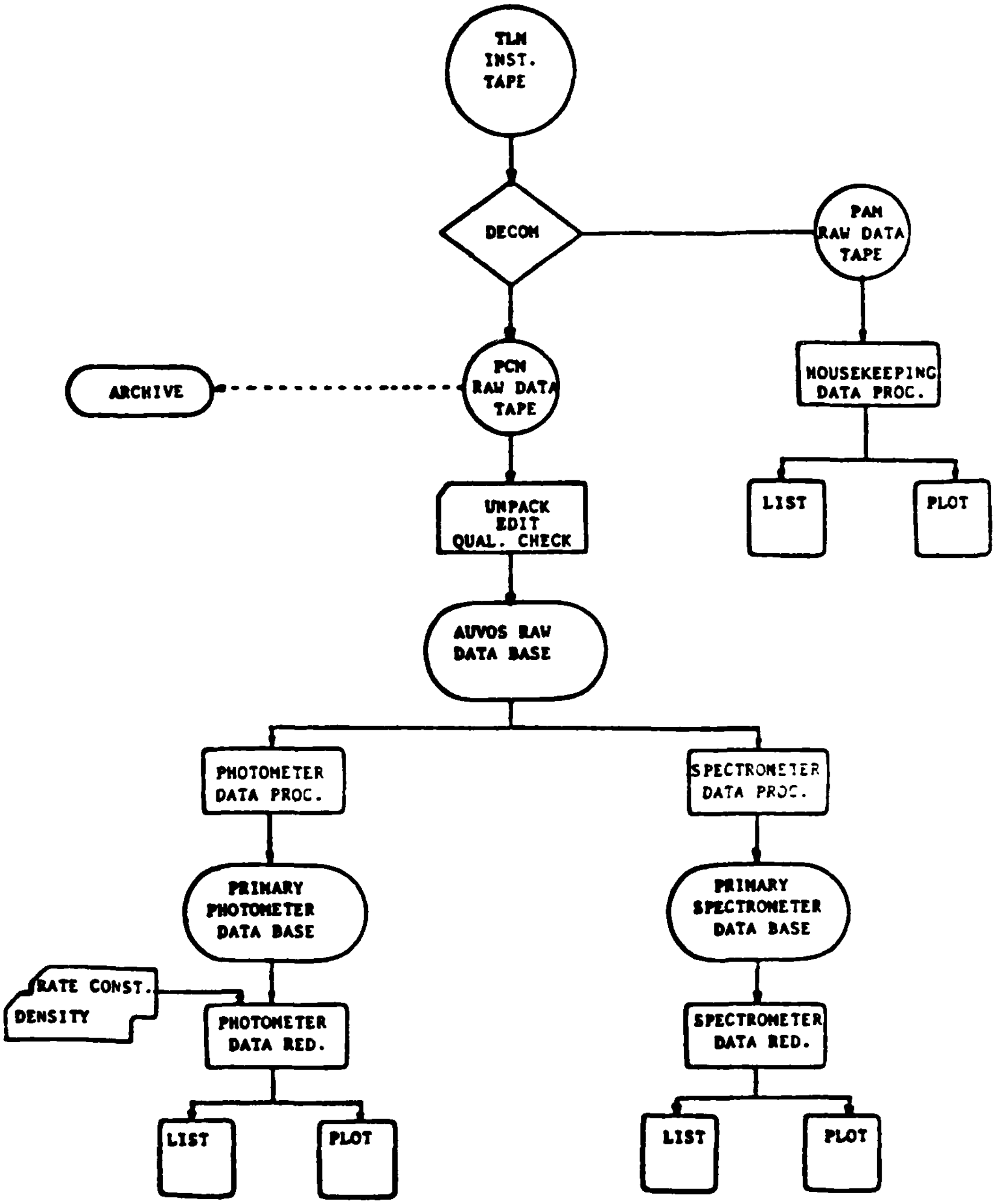

Fig. 8. Flow Chart for Reducing Auroral Data

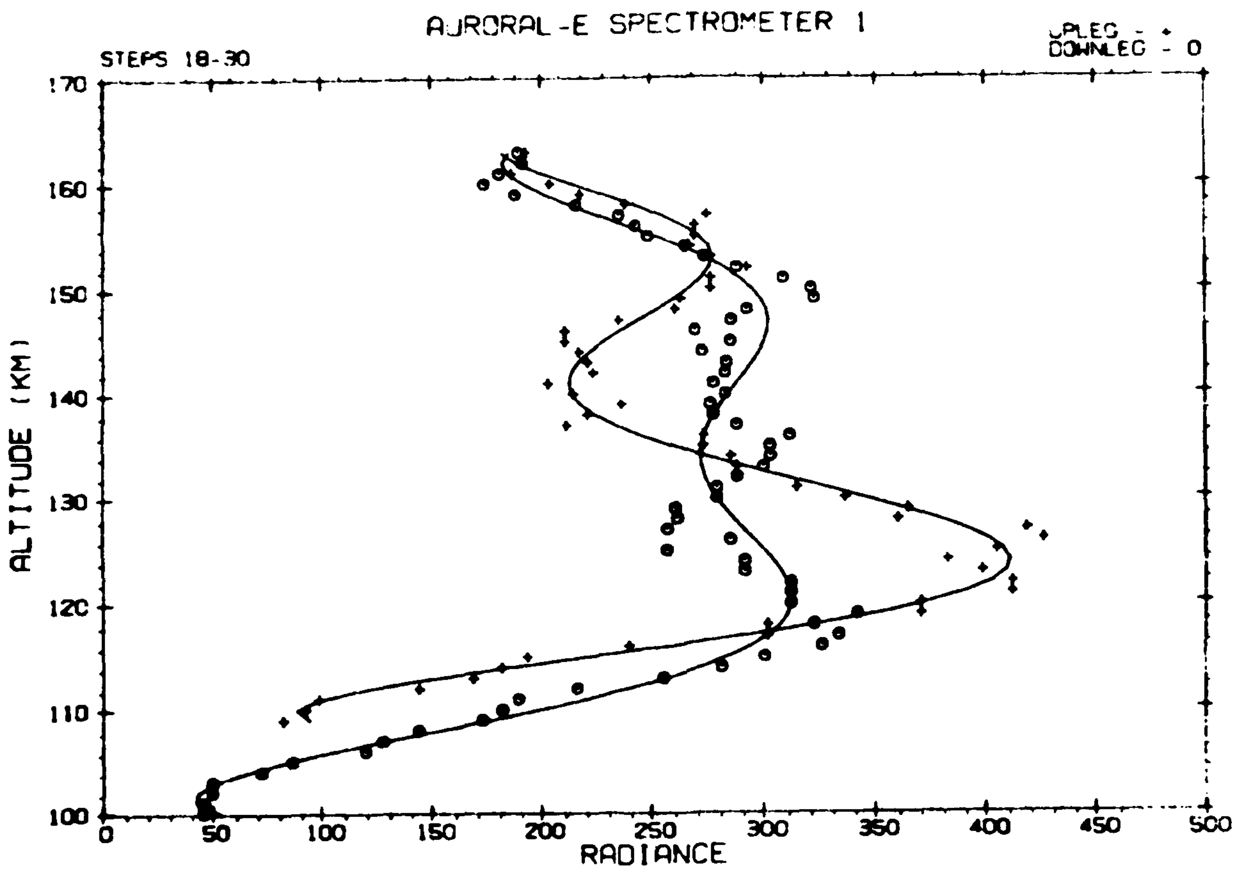

Fig. 9. Curve Fitting Plot for Auroral-E Spectrometer No. 1

H. Photometers/Scintillators

Initiator: A. T. Stair/Phillip Doyle (Optical Physics Division)

Duration: March 1981 - September 1981

Assignment:

Rocket telemetry values were to be processed from chemistry rocket IC819.08-1, flown on February 28, 1978. Requirements included instrument calibration, conversion to engineering units, and analysis of data. The rocket carried photometers PM2-42 and PM2-51 and energy deposition scintillators EDS 75-1, 75-2, and 75-3. Physical parameters were to be listed and plotted as functions of time, altitude, and pitch angle with respect to the earth's magnetic field. Pitch angles were to be merged with the instrument data base from separate flight tapes.

Summary:

Tapes containing instrument data values from the two photometers and three scintillators were converted to CDC format and stored on AFGL tapes. In addition to flight data, the tapes contained a section of pre-flight calibrations for each instrument. These calibrations were used to establish PCM count values corresponding to telemetry volt values of 0.0, 2.5, and 5.0 volts. Then, using a straight-line fit from the calibrations, the data values for each instrument were converted from raw PCM counts to telemetry volts. Pen plots of time vs. telemetry volts were generated for each instrument (Fig. 10). Engineering unit conversions were applied to the telemetry volt data, in order to calculate brightness values in kilorayleighs for the photometers and energy flux in ergs/cm^2 • sec • ster for the scintillators. Listings were produced for each instrument, as well as pen plots of time vs. engineering units, and engineering units vs. altitude, using both linear and logarithmic plot scales.

Data values of rocket altitude and instrument pitch angle were merged from rocket flight tapes into the instrument data base. A new set of listings was generated that included particle pitch angle values for each instrument. Pen plots of scintillator spin were produced, showing pitch angle vs. energy flux. Finally, a set of microfiche plots was generated, covering the entire flight in one-second intervals. Each plot contained one second of scintillator data, plotted vs. particle pitch angle (Fig. 11).

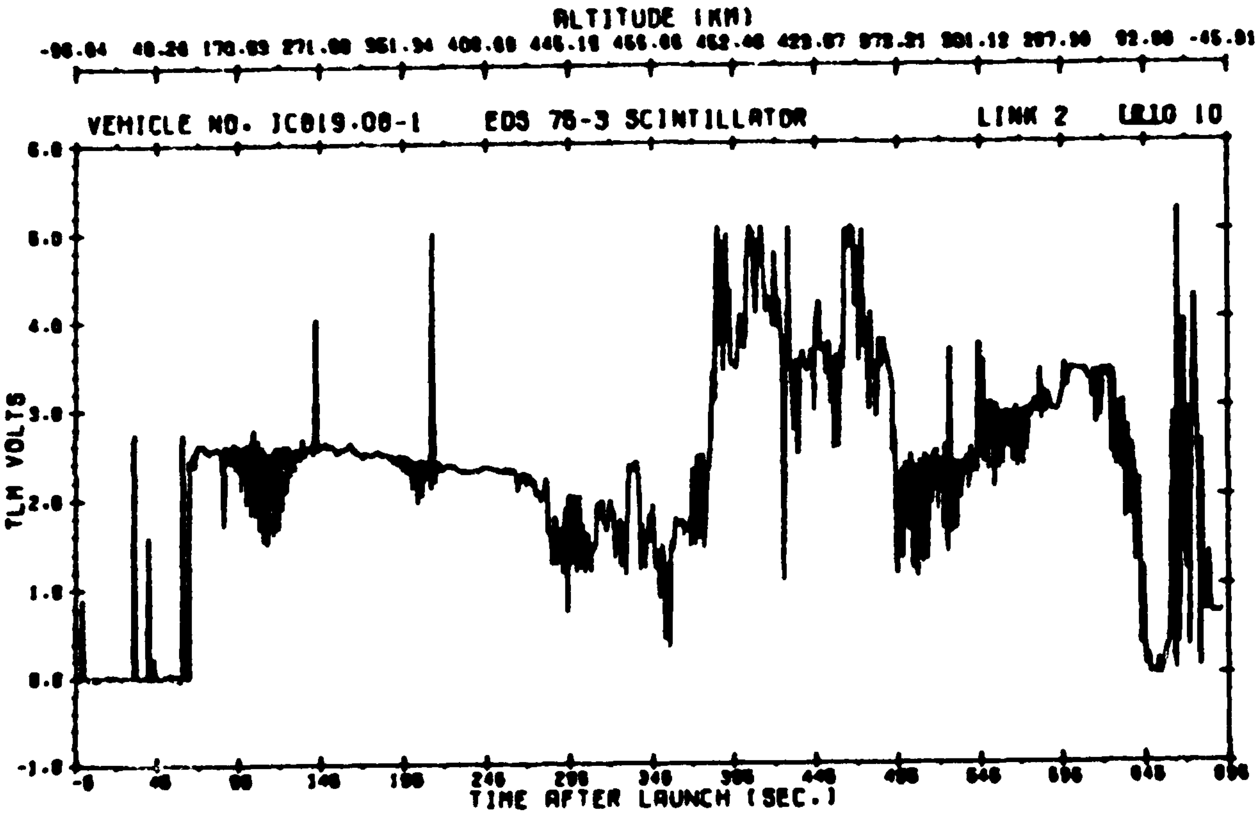

Fig. 10. Plot of Telemetry Volts during Total Flight with Corresponding Values of Altitude

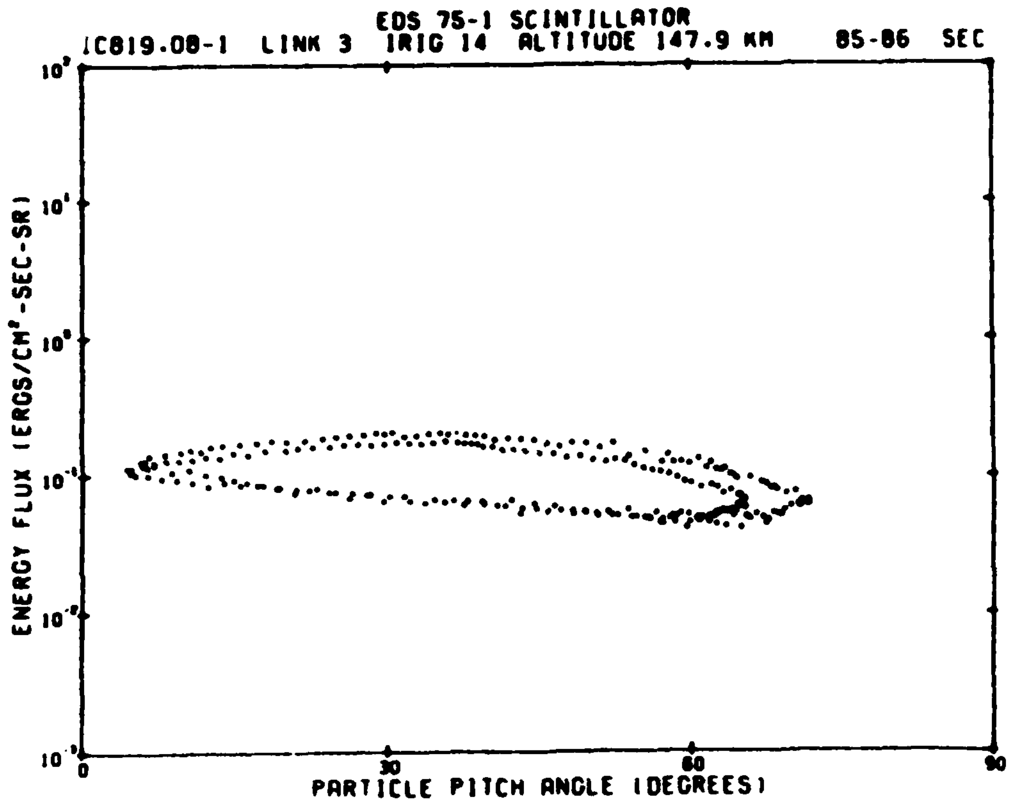

Fig. 11. Energy Flux as a Function of Particle Pitch Angle

Standard software documentation of several listing routines was produced.[4]

4. Analysis and Simulation Branch Project/Problem Library Documentation Worksheets, Problem No. 3138: SD10EFCONVERT, SD10ATTITUDELISTING, SD78ATTITUDE LISTING, SD78EFCONVERT, May 29, 1981.

I. Energy Budget Campaign 1980 (I)

Initiator: Ned B. Wheeler (Optical Physics Division)

Duration: March 1981 - September 1981

Assignment:

Energy Budget Campaign rocket A13.073 flown on November 16, 1980 carried vertical photometers PM2-49, measuring 5577 Å, and PM2-94, measuring 3914 Å. It also carried energy deposition scintillator EDS 75-6 and a DC probe. Rocket A30.072, flown on February 5, 1981, also carried 5577 Å and 3914 Å photometers and a scintillator.

SASC was tasked to calibrate instrument readings, convert them to engineering units, and list and display the data.

Summary:

For the A13.073 flight, instrument data files were unpacked from R-tapes and stored on CC tapes in the CDC format. Calibration values were calculated, and instrument data readings were converted from PCM counts to telemetry volts and engineering units. A listing was produced, and plots of telemetry volts and engineering units vs. time and altitude were generated, using both linear and logarithmic plots scales (see Figs. 12 and 13). The DC probe data values were plotted, with units of current vs. time. Work on this flight was completed under the Straka project (see Section J).

The A30.072 instrument data base was unpacked from R-tapes and stored on CC tapes. Calibration files for each instrument were listed, and PCM count averages were calculated for telemetry volt values of 0.0, 2.5, and 5.0 volts. These averages were used to calibrate the instrument readings. The data base was converted to telemetry volts and engineering units. Data listings were generated for all three instruments. Pen plots were generated showing time vs. brightness for the photometers and time vs. energy flux for the scintillator.

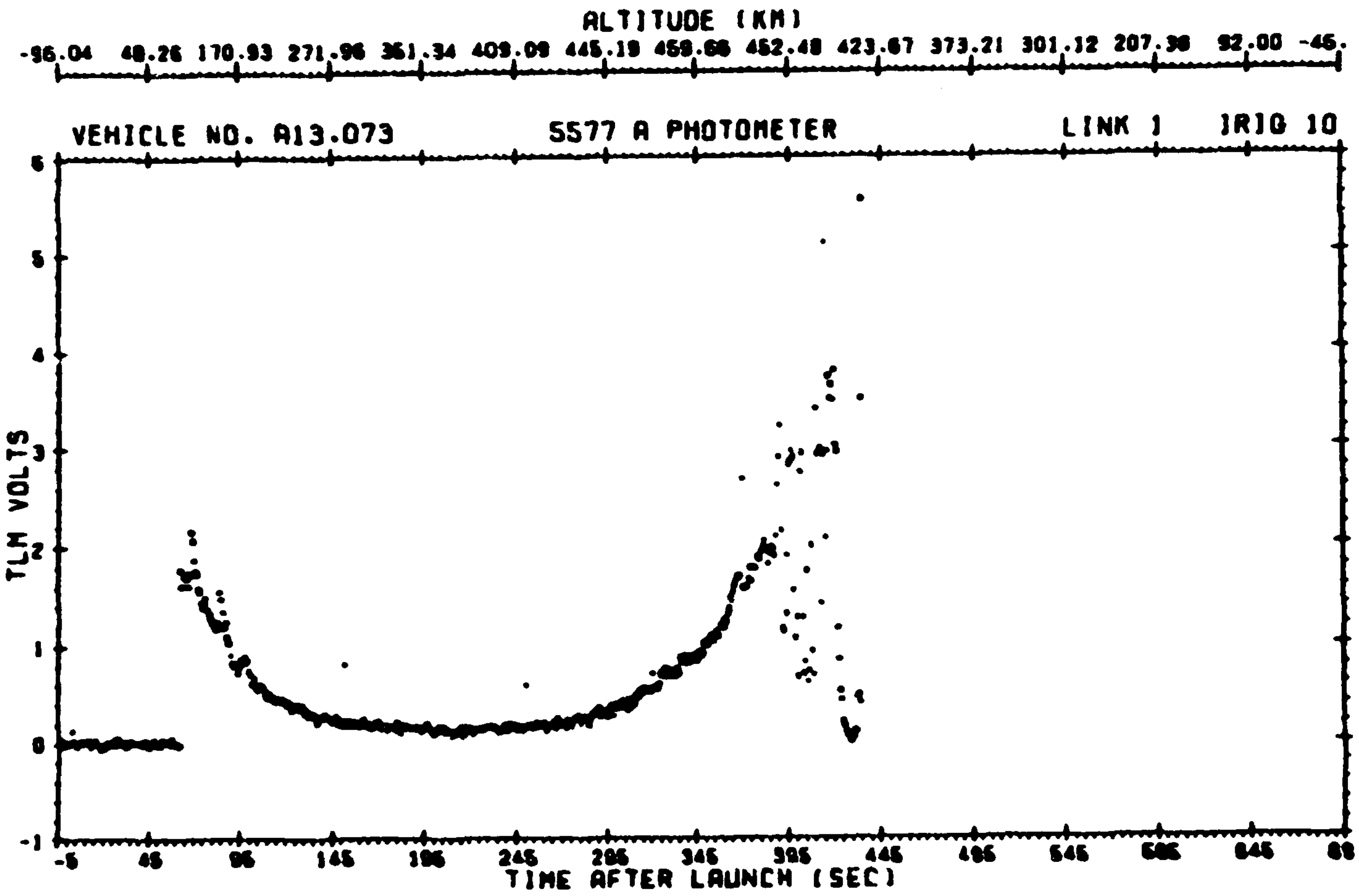

Fig. 12. Display of Telemetry Voltage Output from the 5577 Å Photometer as a Function of Time after Launch and Altitude

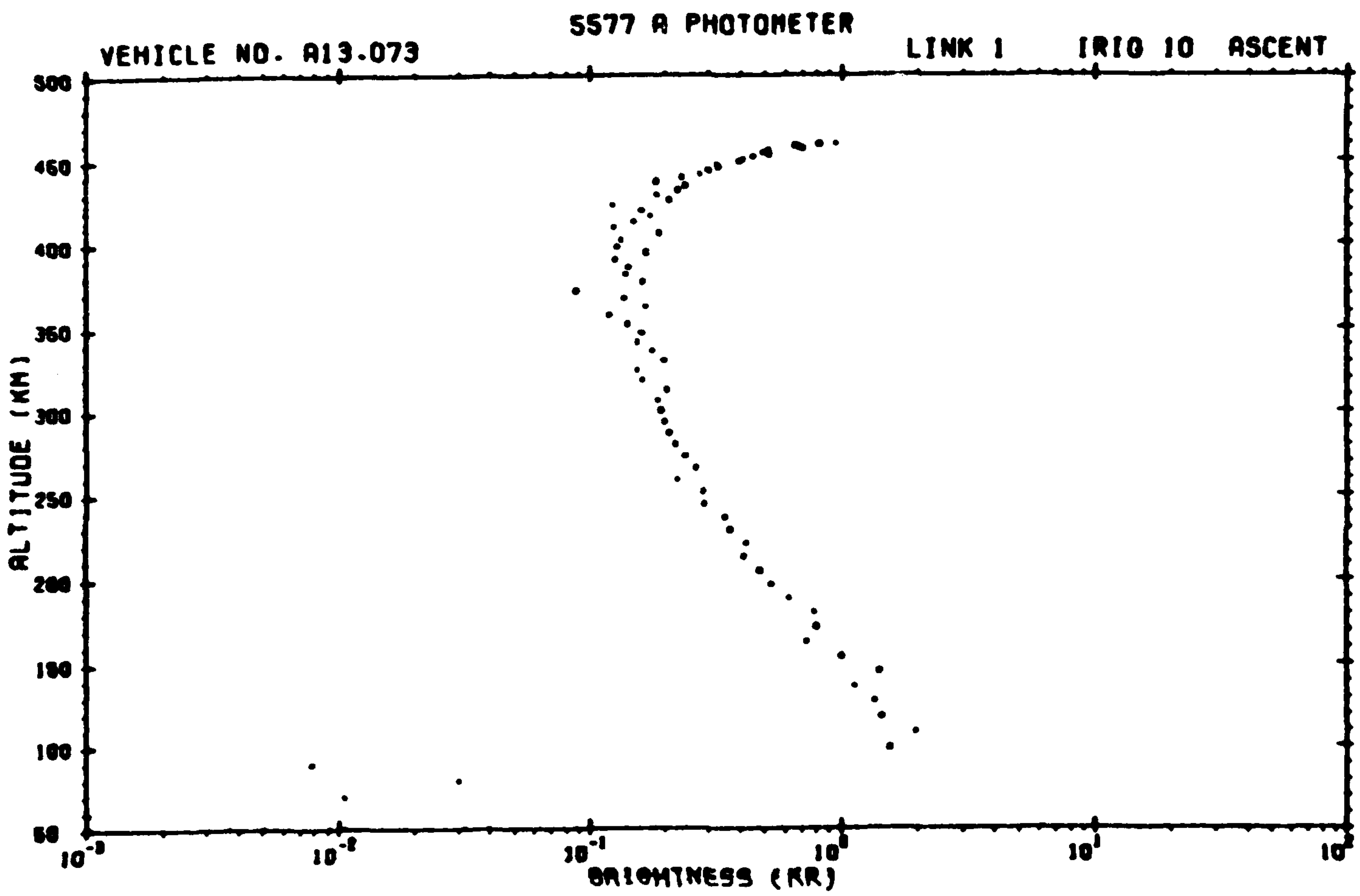

Fig. 13. Brightness vs. Altitude for the 5577 Å Photometer

J. Energy Budget Campaign 1980 (II)

Initiator: Ronald E. Straka (Optical Physics Division)

Duration: March 1982 - September 1982

Assignment:

Rocket IC807.15-1, flown on October 26, 1978, carried two radiometers at 4.3 μ and 2.7 μ, and two photometers, at 4278 Å (PM2-48) and 4259 Å (PM2-56). Each radiometer sent values on three gain channels, 0, 1, and 2. The 0-gain channel on radiometer #2, however, contained no useful data.

SASC's responsibility was to merge the gain channels on each radiometer to provide one composite channel for each radiometer; to calibrate data for all four instruments; and to produce both Tektronix and pen plots. Listings and plots were also to be produced for A13.073 (see Section I immediately above).

Summary:

Plots were generated for scintillator EDS 75-6, showing altitude vs. energy flux (see Fig. 14) and for the photometers, showing brightness vs. altitude (Fig. 15). A 100-point running average was performed on the photometer data, and another set of brightness vs. altitude plots was generated using the averaged values. Particle pitch angle values were then merged into the instrument data base. Using these values, scintillator spin plots were produced on microfiche. Seventeen hundred plots were generated, showing particle pitch angle vs. energy flux in 0.2 second intervals from 60.0 to 400.0 seconds after launch (see Fig. 16).

To process the IC807.15-1 data, an R-tape was first unpacked to CDC format on CC tapes. Data values were averaged over a short time interval and the averages were used to adjust the telemetry volt conversions. Data values were converted to telemetry volts and to engineering units, using instrument-dependent conversion equations. Plots were produced of time vs. radiance (Fig. 17) and radiance vs. altitude for each photometer. Preliminary plots were produced for each gain channel of the radiometers, showing time vs. radiance and radiance vs. altitude. Next, the gain channels were merged for each radiometer, to produce a data base containing instrument values over a wide range while retaining accuracy of measurement. The radiometer data values were replotted, using several plot scales. Pen plots were produced showing the photometers and radiometers with respect to time and altitude.

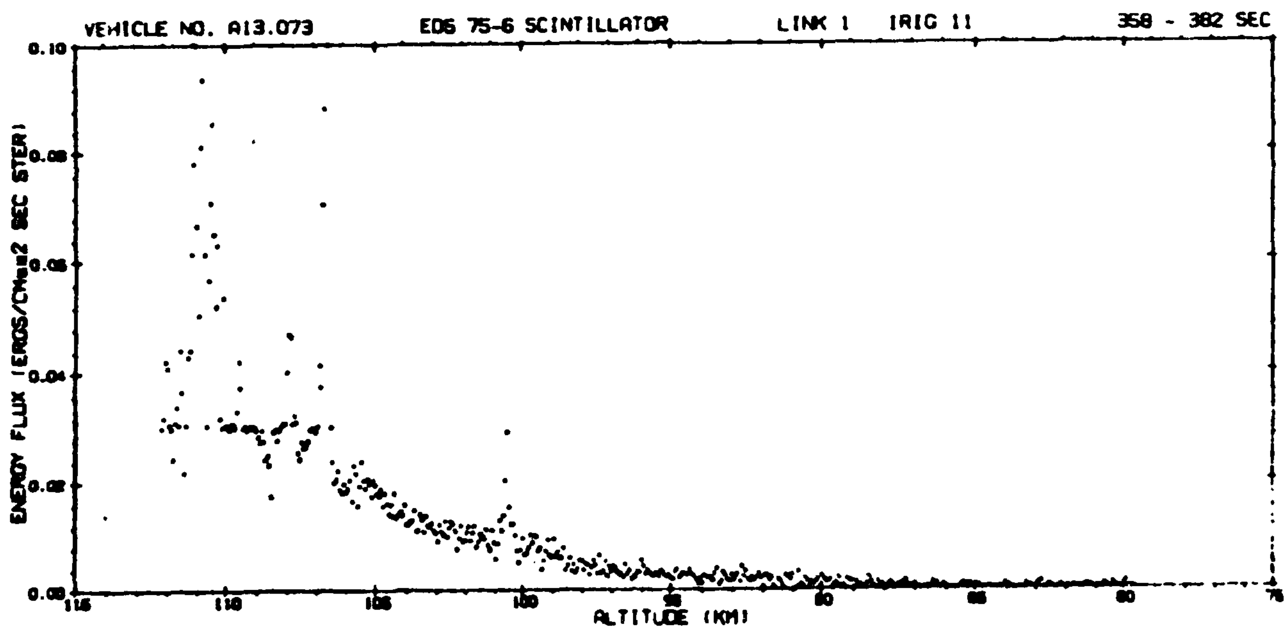

Fig. 14. EDS 75-6 Scintillator during Descent Stage of Flight

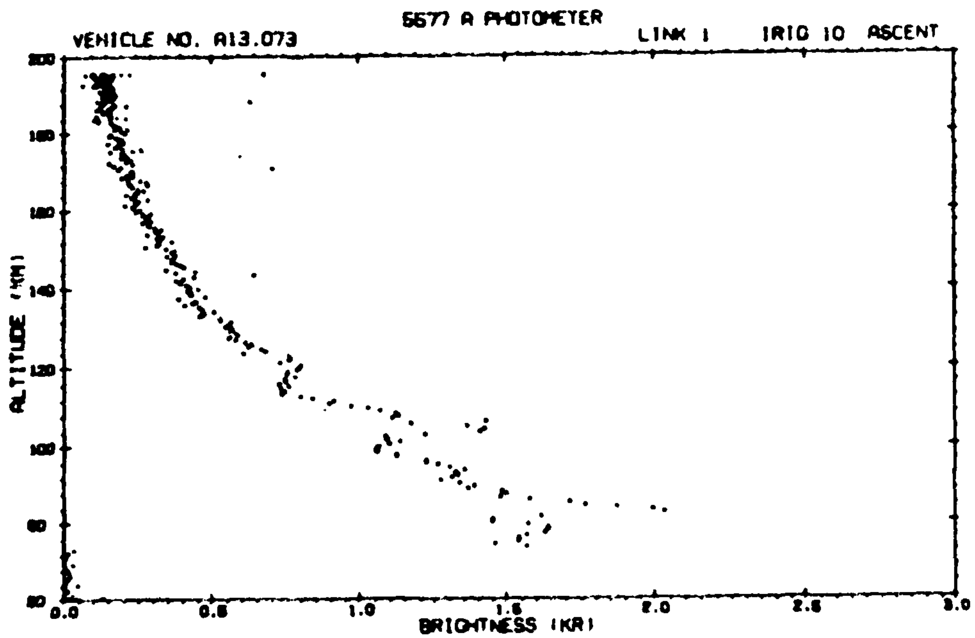

Fig. 15. Plot of Output from 5577 Å Photometer during the Ascent of Rocket

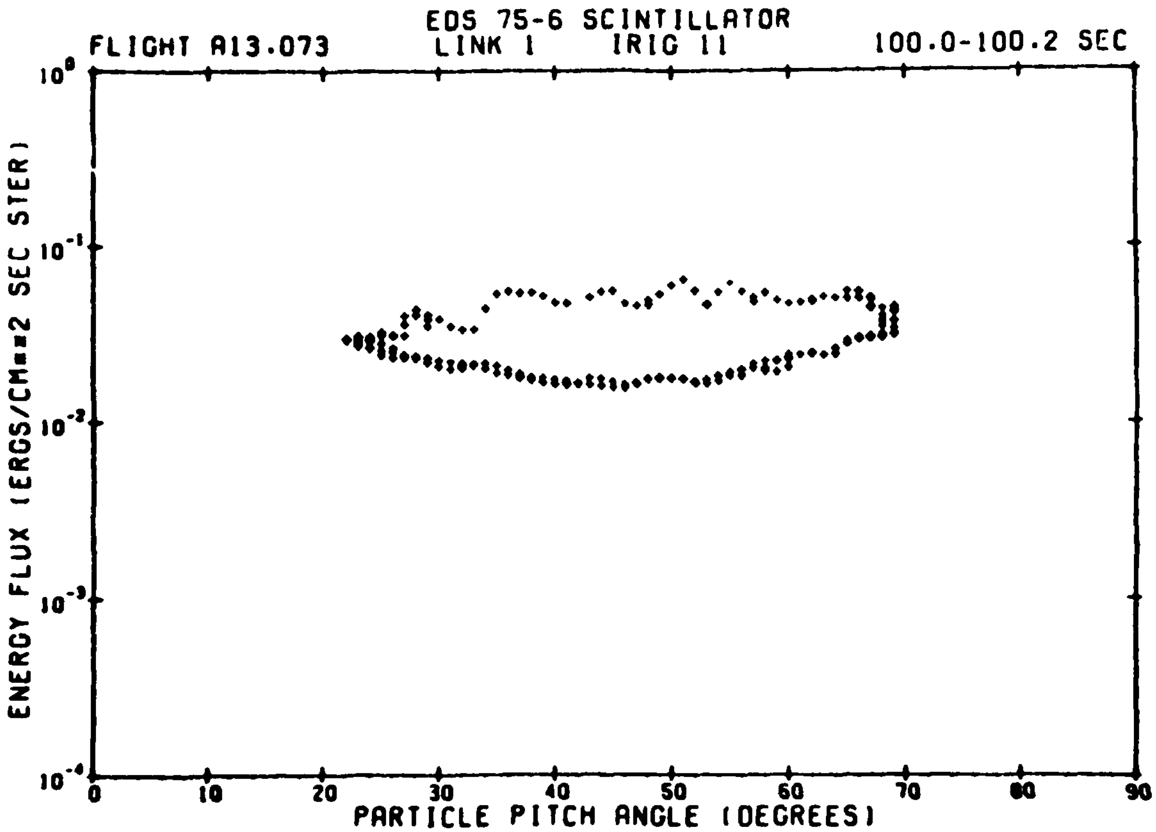

Fig. 16. Display of Energy Flux as a Function of Particle Pitch Angle

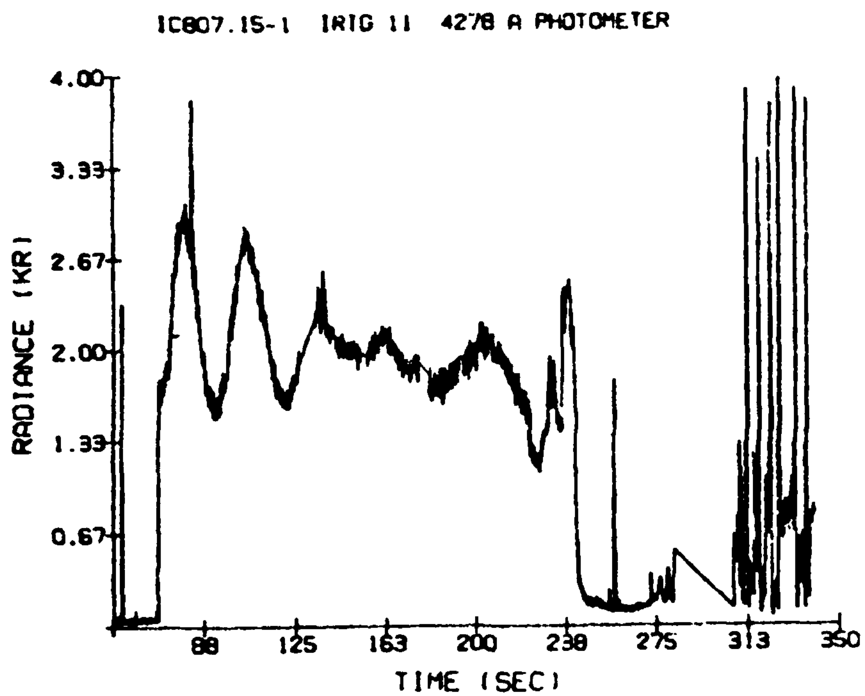

Fig. 17. Radiance as a Function of Time after Launch for the Total Flight

Seven-, 11-, 17-, and 23-point running averages were performed on the radiometer data and another set of plots was produced (see Fig. 18). Finally, the photon emmision ratios of the radiometers and the 4259 Å photometer with respect to the 4278 Å photometer were calculated and plotted vs. time and altitude (see Fig. 19).

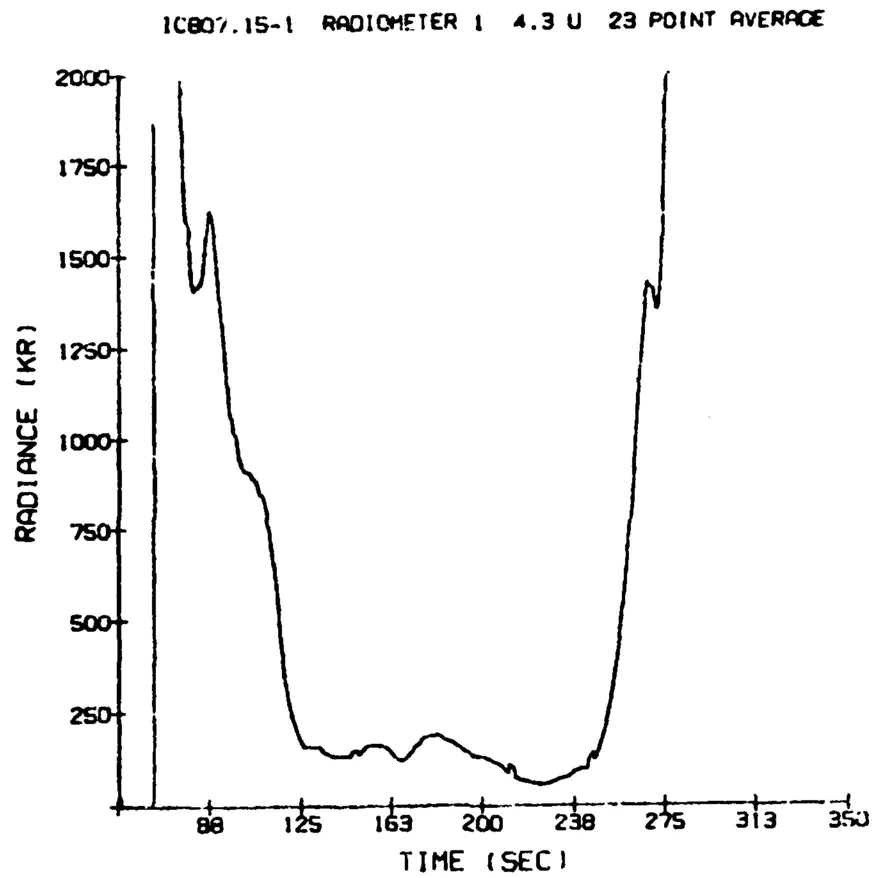

Fig. 18. Twenty-three Point Running Average of Radiances from Radiometer No. 1

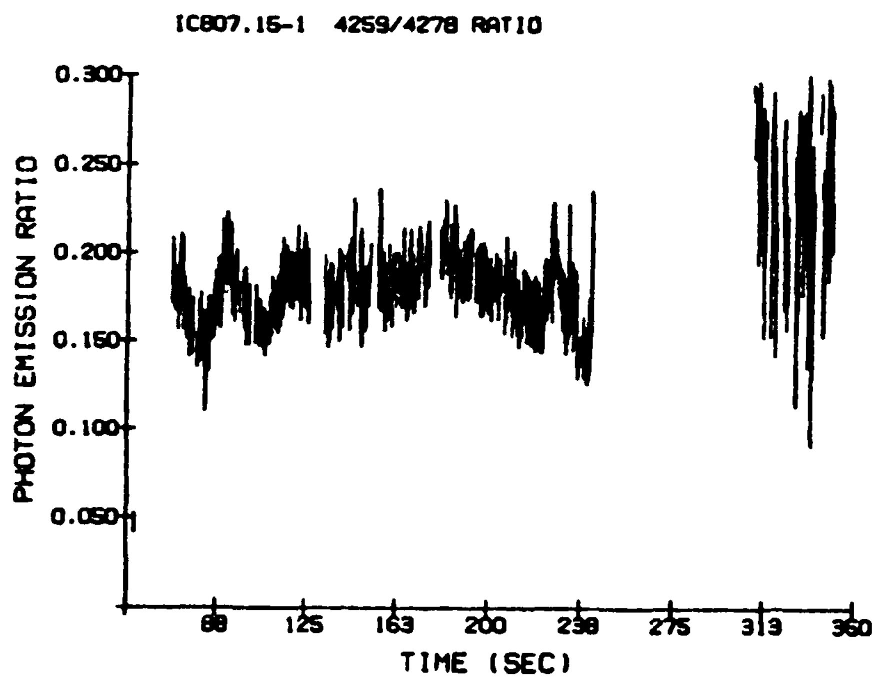

Fig. 19. Photon Emission Ratio of Photometers at 4259 Å and 4278 Å

K. Electron/Proton Analyzer

Initiator: W. J. McMahon (Aeronomy Division)

Duration: October 1981 - March 1982

Assignment:

Two electrostatic deflection analyzers aligned 180° apart were mounted on each of Taurus Orion Auroral-E rockets A13.030 and A13.031. Each instrument measured the energy and angular distribution of auroral electron and proton flux over an energy range of 0.5 eV to 20 keV for electrons and 50 to 60 keV for protons. The analyzers gathered data values by scanning through sixty-four energy steps, and taking a solar flux measurement at each step. The REA-2 and REA-4 rocket flights carried instruments that measured photoelectron flux.

The requirement was to generate a data base of time, altitude, count values, and energy flux for each rocket, and then to merge pitch angle values with the flight tapes.

Summary:

Raw count values were first converted to energy flux values for all four instruments and listings were produced. Scan averages were then calculated for each step over five- to ten-scan intervals. The averaging was performed in a two-step process: first, a preliminary average was calculated for each step; then a second average was calculated, eliminating points which varied by plus 100 percent or minus 50 percent from the preliminary average. This process eliminated data points that were badly out of range. The resulting data values were listed and Tektronix plots were produced using both linear and logarithmic plot scales (see Fig. 20). Next, averages were calculated over five-kilometer intervals and similar plots and listings were produced.

Attitude tapes received for Flts. A13.030 and A13.031 contained pitch angle values of each instrument with respect to the earth's magnetic field. The data values on these tapes were merged with the instrument data files and the resulting data base was used for further plotting. Tektronix and pen plots were produced for each instrument containing energy flux values at selected steps vs. altitude, with a trace of particle pitch angle vs. altitude overlaid on each plot (see Fig. 21).

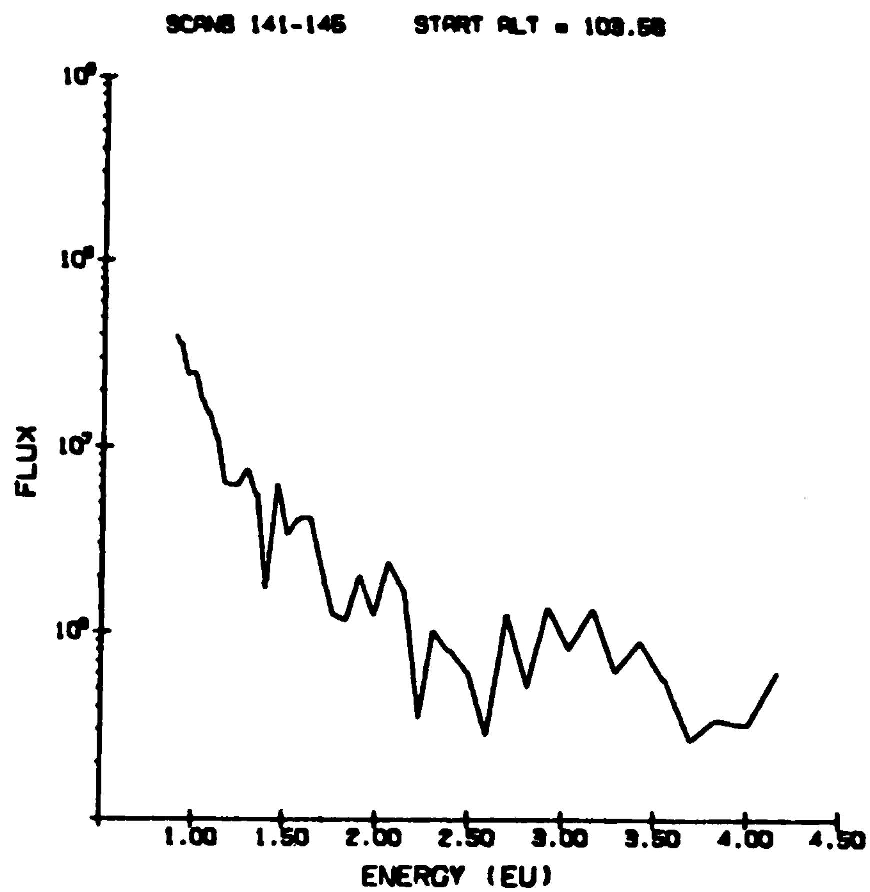

Fig. 20. Plot of Average Flux

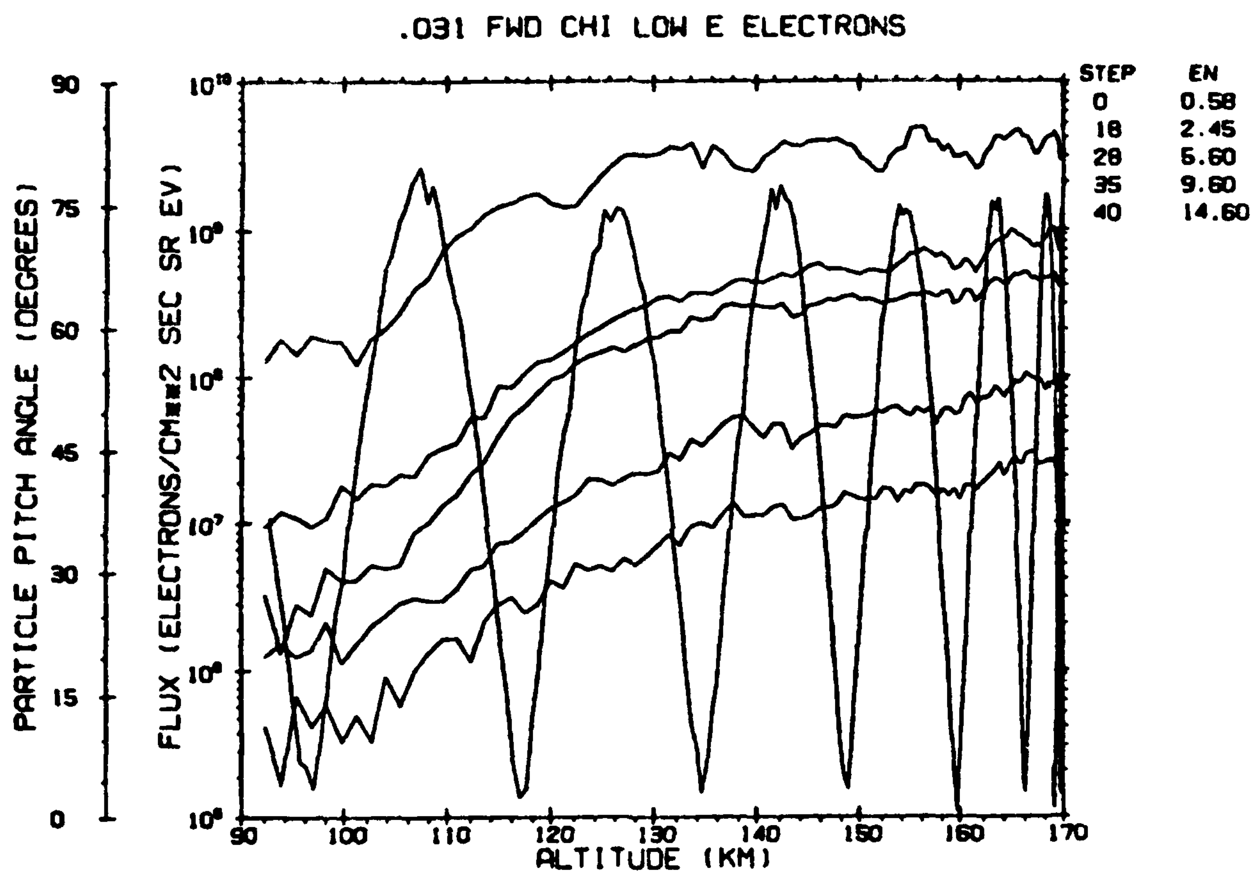

Fig. 21. Overlay of Particle Pitch Angle on Plot of Altitude vs. Energy Flux

For the REA-2 and REA-4 flights, data values were grouped in five-scan averages. Two intermediate functions, a cross-section of the 2PG(0.0) N_2 band$_2$ and N_2 density values from the Jacchia 1977 model were keypunched into the computer. Least-squares polynomial fits were performed on these functions, and Tektronix plots were produced. The REA-2 and REA-4 scan data values were averaged in five-scan intervals and plotted in units of energy (eV) vs. photoelectron flux ($e/cm^2 \cdot sec \cdot ster \cdot eV$), using both linear and logarithmic scales. Finally Tektronix and pen plots of 12 REA-4 scan averages were produced, in units of energy vs. photoelectron flux (see Fig. 22).

Standard software documentation of the routine to display particle pitch angle was prepared.[5]

5. Analysis and Simulation Branch Project/Problem Library Documentation Worksheet, Problem No. 4032: MCPITCHPLOT, February 26, 1982.

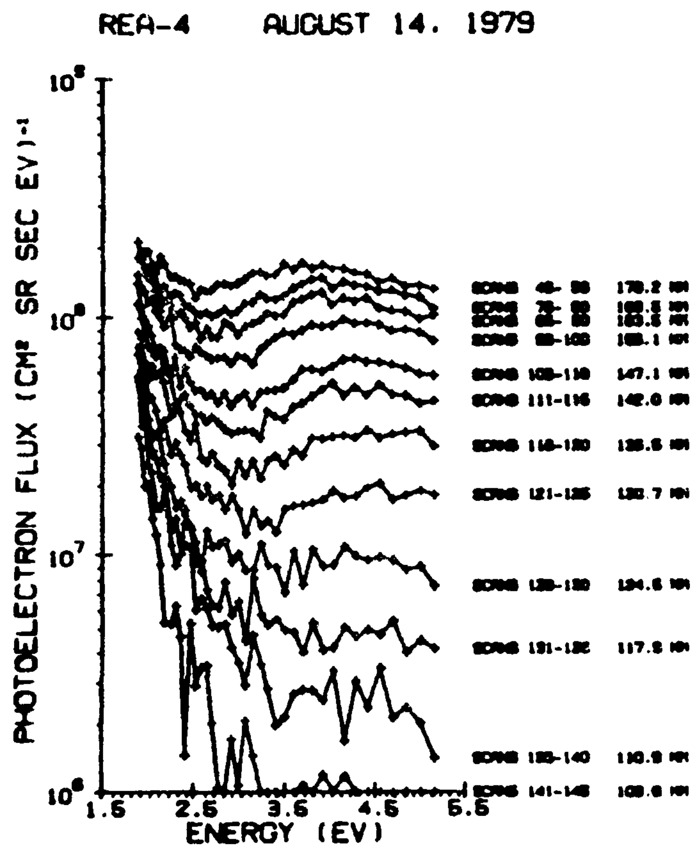

Fig. 22. REA-4 Photoelectron Flux over 12 Scan Intervals

L. Auroral-E Filter Photometers

Initiator: Roger A. Van Tassel (Aeronomy Division)

Duration: January 1982 - January 1983

Assignment:

Nine photometers aboard the Auroral-E research rocket A13.030 measured radiation from isolated molecular bands. SASC's objective was to compute apparent column emission rates for a line, band, or continuum, according to the characteristics of each photometer, and to produce plots for each photometer.

Summary:

Preliminary plots of the nine photometers were produced in units of signal vs. time, altitude (ascent and descent). Intermediate constants and functions needed for computing the line and band emission rates were then calculated. The relative spectral response $\eta(\lambda)$ was calculated by fitting a second-order polynomial to the instrument calibration files. The spectral distribution of intensity $\beta(\lambda,T)$ was needed for computation of the band emission values. Functions for the Vegard-Kaplan and N_2 second positive bands were used to produce listings and three-dimensional plots (see Fig. 23). With these values, the integral of $\beta(\lambda,T) \cdot \eta(\lambda)$ was calculated for each band instrument over nine temperature values from 200 to 1000° K. The line, band, and continuum constants were calculated and applied to the photometer data. Tektronix plots of all nine photometers were produced, in units of column emission vs. time, altitude (ascent and descent). Several plot scales were used for each instrument (see Fig. 24).

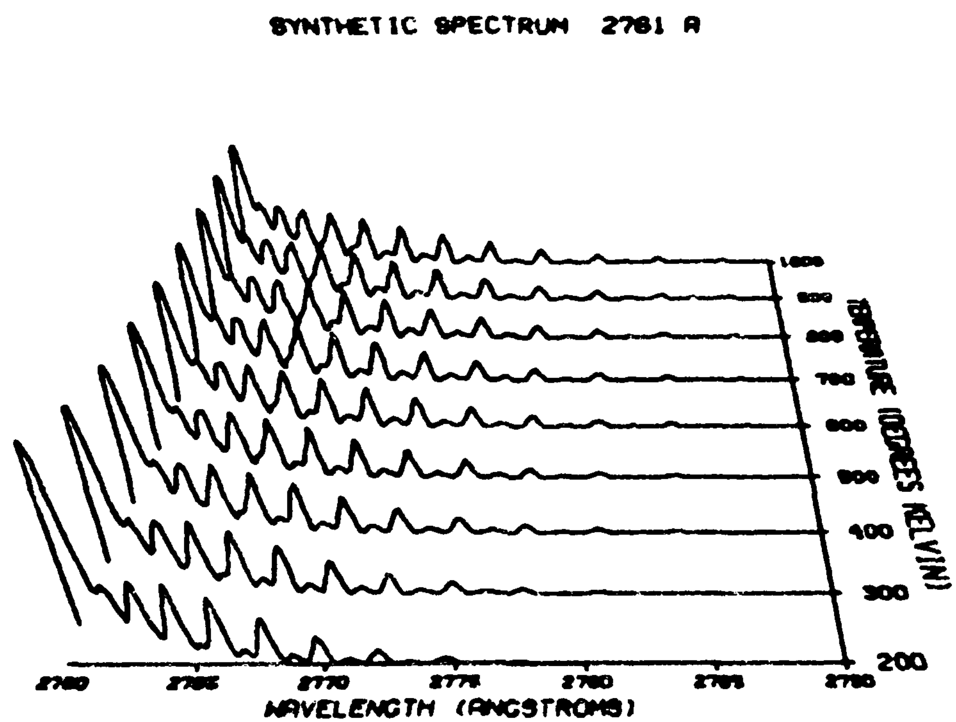

Fig. 23. Three-dimensional Plot of the Relative Spectral Response as a Function of Wavelength over the Temperature Range 200 - 1000° K

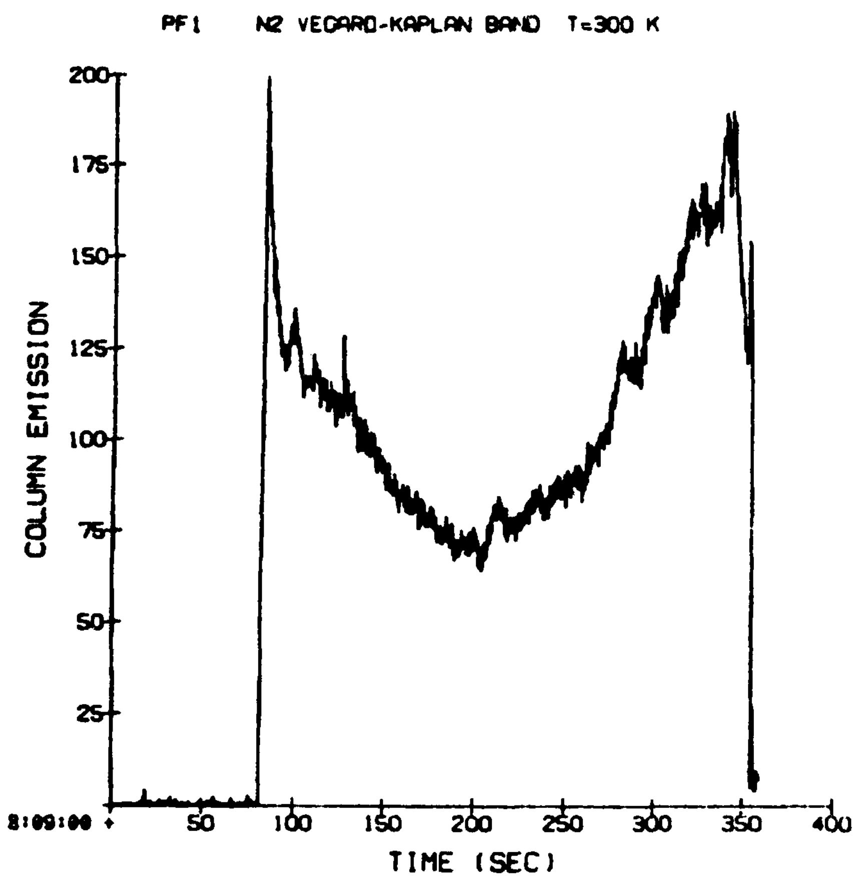

Fig. 24. Photon Column Emission in the N_2 Vegard-Kaplan Band over Total Auroral-E Flight

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